Testing the Fidelity of Peridotite Xenoliths as Records of Water in the Lithospheric Mantle

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Peridotite xenoliths, brought to the surface in volcanic eruption, provide an opportunity to constrain the water content of the mantle. However, rapid diffusion of water in olivine and pyroxene, and thus the potential for chemical exchange with the host magma, raises concerns as to the fidelity of xenoliths in preserving mantle water contents [1,2]. A problem in addressing these concerns is that xenolith studies seldom if ever report the water concentration of the magma host. This study aims to provide such context for peridotite xenoliths erupted from a scoria cinder cone north of the Grand Canyon.

Small peridotite xenoliths bombs were sectioned, doubly polished, and analyzed by ion probe and FTIR. Olivine from the xenolith and scoria phenocrysts have the same core (5 ± 1 ppm) and rim (3 ± 1 ppm) concentrations. IR spectra reveal variations in the olivine H defect structure across the xenolith: exterior olivines reveal H associated with trivalent cation defects (Tri) and reversely zoned H hosted in metal vacancies. Interior olivines lack Tri defects and all defects are normally zoned. Xenolith clinopyroxenes have 459 - 607 ppm water, and orthopyroxenes have between 168 - 399 ppm water. The highest values were found in crystal cores and the lower values at the rims, consistent with diffusive water loss in all three minerals. Olivine-hosted melt inclusions from the host scoria contain up to 2.7 wt% H_2O [3]. Using concentration dependent mineral-melt partitioning relationships [4], we find that the pyroxene cores are consistent with equilibrium with the undegassed host magma. Olivine water concentrations, however, are too low to be in equilibrium with the inferred parental magma.

We conclude that the xenolith minerals have significantly interacted with the host magma during transport, potentially erasing entirely the original mantle water concentrations. Due to its greater diffusivity, H in olivine continued to further equilibrate with the host magma as it degassed. This study shows the importance of examining the water content of the host magma along with peridotite xenoliths. The high temperatures and relatively slow ascent of alkali basalts that erupt in cinder cones may not be favorable to the preservation of mantle water in xenoliths.

[1] Demouchy et al 2016. [2] Ferriss et al 2016. [3] Plank and Forsyth 2016. [4] Adam et al 2016.